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THE ECONOMICS OF NAVAL SHIP AUTOMATION: AN ANALYSIS OF PROPOSED AUTOMATION OF THE DE-1052. EXECUTIVE SUMMARY

Robert Shishko

RAND Corporation

Prepared for:

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PREFACE

This report was prepared as part of Rand's DoD Training and Manpower Management Program, sponsored by the Human Resources Research Office of the Defense Advanced Research Projects Agency (ARPA). With manpower issues assuming an ever greater importance in defense planning and budgeting, the purpose of this research program is to develop broad strategies and specific solutions for dealing with present and future military manpower problems. This includes the development of new research methodologies for examining broad classes of manpower problems, as well as specific problem-oriented research. In addition to providing analysis of current and future manpower issues, it is hoped that this research program will contribute to a better general understanding of the manpower problems confronting the Department of Defense.

In 1973 Rand was asked by the Human Resources Research Office and the Tactical Technology Office of ARPA to evaluate on economic grounds a specific proposal by a Purdue University team headed by Prof. Theodore J. Williams of the Laboratory for Applied Industrial Control to automate the DE-1052 class destroyer escort. At that time, the Navy was already funding a number of surface ship automation programs, but none of these was designed to look at the "maximum" automation of a Navy surface ship. The full state-of-the-art automation of a Navy ship was the goal of ARPA and the Purdue group. Assisting the Purdue group in this effort was a group from Specialized Systems Inc. of Mystic, Connecticut, with extensive experience in shipboard personnel matters. Rand worked closely with both groups but reported its findings directly to ARPA.

This executive summary encapsulates the issues and results from *The Economic of Shipboard Automation: An Analysis of Proposed Automation of the DE-1052*, R-1790-ARPA.

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Responsibility for any errors remains, of course, the author's.

THE ECONOMICS OF SHIPBOARD AUTOMATION: AN ANALYSIS OF PROPOSED AUTOMATION OF THE DE-1052--EXECUTIVE SUMMARY

The objective of this study is to provide an economic analysis of a proposal to automate the DE-1052 class destroyer escort. Although the study is directed toward a specific proposal from the Purdue Laboratory for Applied Industrial Control, several larger lessons can be drawn from it concerning future naval ship automation.

The principal benefit of shipboard automation is the reduction in the manpower necessary for operation and maintenance of the ship. To realize this reduction, R&D expenditures must be made and automation hardware must be acquired, installed, and brought to operational status.

To determine the manpower savings attributable to automation, the manning of an automated DE-1052 is compared with that of an efficiently manned current DE-1052, holding ship effectiveness constant. The level of manning of an efficiently manned DE-1052 is called here "austere manning." Comparison of the austere manning structure with the manning structure of an automated DE-1052 permits ascertaining of the *net contribution* of automation to manning reduction. Because both ships are manned so as to be equally effective, arguments as to the desirability of the proposed automation can be focused on economic considerations alone. Whether the shipboard automation is economically advisable depends upon the dollar value of the manpower savings attributable to automation, the dollar costs of the automation, and the timing of these savings and costs.

To establish the enlisted manning required for the austere and automated DE-1052, all currently assigned stations in Conditions I *(General Quarters)* and III *(Wartime Steaming)* were examined for possible manning reductions or changes;[1] the number of enlisted personnel

[1] Several constraints on manpower reductions were imposed on the analysis. Weapons systems were assumed to be sufficiently automated so no changes in manning were considered. No changes in officer billets were considered, and changes in manning in the Combat Information Center (CIC), Communication Control (CC) and Damage Control (DC) parties were allowed only at interfaces with other departments. As with all limitations, these constraints have their implicit or shadow costs.

not currently assigned to any station[1] was assumed to be variable according to total shipboard manning.

The difference between the austere manning (234) and the automated manning (189) is the net reduction attributable to automation (45). What is important is not so much the number of individuals saved by automation but the kinds of personnel saved. The cost of highly skilled or experienced personnel may be substantially greater than the cost of low skilled or inexperienced personnel, or the retention of some ratings may be more difficult than others. Table S-1 shows how the reduction of 45 enlisted personnel (per ship) is distributed over skill and experience categories.

Table S-1

PERSONNEL CHANGES ATTRIBUTABLE TO AUTOMATION
BY SKILL LEVEL AND EXPERIENCE

	Experience (term of service)		
Skill Level	1st	2nd	3rd and Above
High[a]	-1	0	0
Medium[b]	-5	-4	-2
Low[c]	-32	-1	0

[a]Includes IC rating.

[b]Includes BM, BT, EM, EN, MM ratings.

[c]Includes QM, SK, SM, SN/FN, YN ratings.

RETENTION UNDER AUTOMATION

Automation is not likely to have an adverse effect on, and may help, the Navy's efforts to retain individuals in the BT, EM, EN, IC, and MM ratings while holding the line on bonus payments. For the QM and SM ratings, automation may be helpful in eliminating some retention problems. In fact, the proposed automation of the DE-1052 may have a *fleetwide* effect by allowing for a reduction in the Selective

[1]Unassigned personnel generally perform hotel-type functions.

Reenlistment Bonus (SRB) paid to all individuals in the QM and SM ratings independent of whether they serve on a DE-1052. The effect would, however, be significantly greater if automation could be focused more on eliminating (high-skill and) high-experience personnel.

The manpower reduction attributable to automation was converted to a dollar figure by multiplying the number of enlisted personnel saved in each rating and paygrade by an estimate of the total annual cost for each rating and paygrade. This total annual cost in 1974 dollars is the sum of five separate, annualized costs--basic costs, training costs, retirement costs, reenlistment costs, and Permanent-Change-of-Station (PCS) costs.

Table S-2 summarizes the results of the calculations in the same format as Table S-1.

Table S-2

ANNUAL PERSONNEL-RELATED SAVINGS ATTRIBUTABLE TO AUTOMATION[a] (per ship)

Skill Level[b]	Experience (term of service)		
	1st	2nd	3rd and Above
High	$13,600	0	0
Medium	$64,900	$49,900	$26,700
Low	$268,300	$12,100	0

[a]At a discount rate of 10 percent; total annual savings per ship, $435,500.

[b]Ratings associated with each of the three skill levels are identical to those in Table S-1.

INVESTMENT COST OF AUTOMATION

Although some equipment for the proposed automation is off-the-shelf hardware, other equipment as well as software will have to be developed and tested. Precise estimates of the cost of the proposed automation are therefore not possible. The best estimates that could

be obtained by Rand represented a range of guesses that were provided by traditional suppliers of this kind of equipment to the Navy.[1] The lack of precise cost estimates need not be a stumbling block if confidence in the manpower saving estimates is high.

For the DE-1052, nonrecurring development engineering costs were estimated to be between $3.5 and $5 million. The per ship conversion costs--which include hardware acquisition, installation, checkout, and sea trials--were estimated to be between $3.0 and $4.25 million. A per ship conversion cost of $3 million will be referred to as the "low" estimate and a per ship conversion cost of $4.25 million as the "high" estimate. The reason for a range of estimates is uncertainty as to the details of the specifications required to gain Navy acceptance. The low estimate reflects an expectation that "ruggedized" versions of commercial hardware but with some equipment built to military specifications (mil-spec) will be acceptable, and the high estimate reflects the expectation that strictly mil-spec equipment will be required. The Navy of course will affect the costs of the hardware by the very way it writes the specifications.

NET RETURN TO AUTOMATION

To calculate the net return to automation it is necessary to specify a schedule for the R&D and retrofit programs. During these phases, the development and conversion costs of automation are incurred; as automated DE-1052s are phased into the fleet, the dollar savings due to reduced manpower needs are realized. The schedule is an important consideration because costs and savings occurring in different years must be discounted to make them commensurable.

To make the calculation of the net return concrete, a schedule is chosen consisting of a three-year R&D program and a three-year retrofit program; the retrofitted DE-1052s are assumed to remain in fleet service for 15 years. Retirement of the last automated DE-1052s is assumed to

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[1] These suppliers preferred to remain anonymous since formal bids had not been requested. Their names would be recognized as important firms in the boiler, marine powerplant, control equipment, and electronics fields.

be completed by the end of 1995. A DE-1052 entering operational status in 1970 will then have been in fleet service for a total of 25 years, which is about current practice.

The present discounted value (PDV) calculation reduces the stream of costs and savings to a single number so that the proposed automation can be compared with alternative investments having different time paths of costs and savings.[1] If the correct discount rate is used, the PDV represents the payoff of the proposed project. If the PDV is negative, the project should, of course, not be carried out because the real resources consumed exceed the savings generated, when costs and savings are measured in commensurable units.

Table S-3 shows the results of the PDV calculation for several selected cases. In these cases, the program size, discount rate, and the estimated cost of automation are varied over the range of uncertainty that prevails for each.

At a recommended discount rate of 10 percent, the proposed automation has a decisively negative PDV when the cost of automation is at the high end; when the cost of automation is at the low end, the proposed automation has a small positive PDV. At a discount rate of 5 percent, the proposed automation has a small but positive PDV at the high estimate and a decisively positive PDV at the low estimate. This suggests that the PDV is moderately sensitive to the choice of the discount rate and to the cost of automation. At a discount rate of 15 percent, the proposed automation has a negative PDV at both the high and low cost estimates.

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[1]The PDV in constant 1974 dollars can be calculated by the following formula: Let r be the discount rate, then

$$PDV = \sum_{t=1}^{n} (-C_t + S_t)(1 + r)^{-t}$$

where C_t is the cost of automation in constant 1974 dollars incurred in year t and S_t is the personnel-related savings in constant 1974 dollars in year t.

Table S-3

PDV OF PROPOSED AUTOMATION
(millions of 1974 dollars)

Case[a]	Program Size[b]	Cost of Automation[c]	Annual Discount Rate	PDV	PDV Per Ship
I	62 ships	High	10%	-40.34	-.65
II	62 ships	Low	10%	9.17	.15
III	62 ships	High	5%	6.10	.10
IV	62 ships	Low	5%	68.23	1.10
V	46 ships	Low	5%	49.80	1.08
VI	62 ships	High	15%	-56.61	-.91
VII	62 ships	Low	15%	-16.72	-.27

[a]All cases refer to the schedule described above and in the text.

[b]The Knox (DE-1052) class comprises 46 ships; the Knox, Garcia (DE-1040), and Brooke (DEG-1) classes comprise 62 ships.

[c]Terms are defined above.

Further sensitivity analyses revealed that at the high cost of automation and a discount rate of 10 percent, the PDV (in constant dollars) is still negative even if (1) the personnel-related savings were underestimated by 10 percent, or (2) the rate of inflation in military wages is unrealistically and persistently larger than that for military equipment over the next 20 years.

CONCLUSIONS

The desirability of any particular automation scheme depends not only on the number of individuals but on the kinds of individuals saved. To make this point more dramatically, consider the proposed automation of 62 DE-1052 and DE-1052-like ships. At a discount rate of 10 percent and a high cost of automation, to break even, an additional $135,400 would have to be saved per ship per year. (Note that this is about 30 percent more than the estimated savings.) This dollar figure translates into 11 additional trained individuals in the medium or high skill category, assuming an average annual per capita cost of $12,700. But the

same dollar figure translates into 18 additional untrained individuals--that is, SN or FN--at an average annual per capita cost of $7,800.

With the same mix of trained and untrained individuals as the proposed automation already saves, then an additional 15 (or 33 percent more) individuals would have to be saved for the project to break even. This figure was obtained assuming an average annual per capita cost of $9,700.

The PDV of the proposed automation is negative (at the high cost of automation) or marginal (at the low cost of automation) at the recommended discount rate of 10 percent. The reasons for this are not only because of insufficient manpower savings, the point made above, but also because retrofitting the automation into an existing ship involves at least three additional losses. First, the number of years of operational life remaining on an existing DE-1052 is less than on an entirely new ship, reducing the time over which automation investment expenditures can be recovered. Second, the retrofitting of the automation equipment into an existing DE-1052, even if pursued during a regular overhaul sequence, involves the expensive procedure of removing and then replacing various parts of the boiler and powerplant; checkout and sea trials must be repeated as well. Installing the automation equipment on a new ship would be considerably easier and less costly; checkout and sea trials could be accomplished as a part of the regular process of bringing the ship to operational status. Third, the automation for a new ship might well be more efficient because designers would not be constrained to adapt it to the DE-1052, a ship that was not necessarily designed with boiler and powerplant automation in mind. In particular, automation may allow for smaller and more fuel-efficient ships, which would lower initial capital and operating costs as well. For these reasons, the economics of the automation of future naval surface ships is quite a bit more favorable than the automation of existing ships.

For the proposed automation of the DE-1052, the PDV is very sensitive to the estimated cost of automation. This is the one area in which better information would have a very high payoff. The cost estimates used in this analysis are not meant to be upper and lower bounds; these

estimates could be off by a factor of two or more. Therefore, it is strongly recommended that better cost estimates be obtained.

The optimal degree of automation is not revealed by the present analysis. Although "total" automation of the DE-1052 does not seem to be worthwhile, selective automation of certain functions *may* be. One very promising area for improvement is interior communications.

Improved shipboard manpower management may have a high payoff. Improvements in shipboard manpower management and training may be possible that will make both unautomated and automated ships less manpower-intensive by reducing (1) the number of personnel who are assigned in Condition I but not assigned in Condition III, (2) the number of personnel who are needed for Condition III but who have no Condition I assignment, and (3) the number of unassigned personnel--that is, personnel who have no assignment in either Condition I or Condition III.